The Prediction of
PROLONGED TEMPERATURE INVERSIONS
NEAR THE WESTERN SHORE OF LAKE ERIE

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ABSTRACT

Temperature inversions at the site of the Enrico Fermi Atomic Power Plant near the western shore of Lake Erie are studied for the three-year period from December 1956 to November 1959. Such inversions in the first 100 feet persisting more than 24 hours are related to certain macroscalar surface synoptic features, to surface wind direction, and to warm air advection. The surface trajectories of air parcels arriving over the plant site during prolonged inversions are classified and discussed. The importance of stagnating anticyclones is then investigated, and lastly, a graphical forecast method is proposed and tested for the prediction of prolonged inversions in this area.

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1. INTRODUCTION

A temperature inversion near the ground often hinders man's activity, and may affect his health adversely. It may persist over an airport to produce a serious fog or haze condition, or over populated areas exposed to industrial smoke and other airborne waste products. In either case, the inversion inhibits vertical motion in the atmosphere. Underneath a low-level inversion, concentrated gases, fumes, or particulate matter may be transported away from the source to an inhabited zone where vertical motion is less retarded. There, the undesirable waste products may reach the ground to pollute the area.

On a shore near a fairly large body of water, one would expect the water to exert considerable influence on the temperature structure of the lowest layers. For example, the well known seasonal lag in surface water temperature would favor springtime inversions, and prior to ice formation in winter, the relatively warm surface water would discourage their occurrence. However, to assume that the persistency of a lakeshore inversion is largely governed by lake waters would not be justifiable, for atmospheric motion, both horizontal and vertical, can upset the aqueous control.

The characteristics of the surface air flow during prolonged inversion periods are examined herein through the study of synoptic charts and wind roses, and by calculating surface trajectories. Effects of vertical motion during these periods are investigated by examining subsidence inversions and the temperature differences at the lake-air interface.

There is utility in the accurate prediction of the onset and termination of prolonged inversions. For example, in the operation of large waste disposal units, such forecasts would be very useful. Therefore, the goal of this paper is to show the effectiveness of combining two promising parameters in a graphical forecast procedure for a particular site. The frequent extensiveness of the kind of inversion which becomes prolonged may well mean that the procedure is applicable elsewhere, in the absence of disrupting local influences.

2. DEFINITIONS

The terms "Inversion", "Continuous Inversion" and "Prolonged Inversion" have the following meanings in this paper.

Inversion: A net increase of temperature with increase in height from 24 feet to 99 feet.

Continuous Inversion: An Inversion which is recorded during consecutive hours, with the exception that isolated hours abstracted from the record as "Missing data" or "Weak lapse rate" are permitted within the series of inversion hours.

Prolonged Inversion: A Continuous Inversion which persists more than 24 hours.

3. INSTRUMENTATION AND DATA SUMMARY

The layer through which the lapse rate was determined was from 24 feet in height to 99 feet in height above a ground elevation of 582 feet. The latter elevation is 10 feet above the mean lake level. The sensing elements were iron-constantan thermojunctions with a time constant of about three minutes and an accuracy of $\pm 0.2°F$. The sensors were installed on a 100-foot steel tower at the Enrico Fermi Atomic Power Plant site, near Monroe, Michigan. The thermocouple

outputs were fed to a stepping switch and then to a recorder registering temperature differences between 5 and 24 feet, 5 and 57 feet and 5 and 99 feet. Transmitters and recorders were also installed on the tower to give wind speed and direction continuously at 24, 56, and 102 feet. Further details on the instrumentation are available (2). A map of the area surrounding the plant site is presented in Fig. 1.

Soon after the implementation of the meteorological tower, a Prolonged Inversion persisted 2½ days at the plant site. This event prompted the compiling of certain inversion statistics, which were published in five Progress Reports (2), (3), (4), (5), and (6), released between 1957 and 1960. The abstracted information for the layer from 24 to 99 feet, giving, for each hour, a classification of "Inversion", "Weak lapse rate", or "Strong lapse rate" is used in this investigation; wind speed and direction information at 100 feet is also utilized.

Fig. 2 gives the monthly occurrence of Prolonged Inversions from December 1956 to February 1961, and Fig. 3 gives the average number of inversion hours per month during this period. There are 10 cases per year, on the average, totaling 365 inversion hours annually. The differences between the two histograms are inconsequential, but the seasonal changes in each are marked. The relative frequencies, by groupings of months, may be summaried as follows:

<u>January - July</u>: Intermediate frequency, averaging about one case per month in February, May and July, and about one case per two months in January, March, April and June.

<u>August - October</u>: Very low frequency, with no cases at all in August, one in September, and a total of two in October.

<u>November - December</u>: Relatively high frequency, especially in December, with a Prolonged Inversion present 2.4 percent of the time in this month.

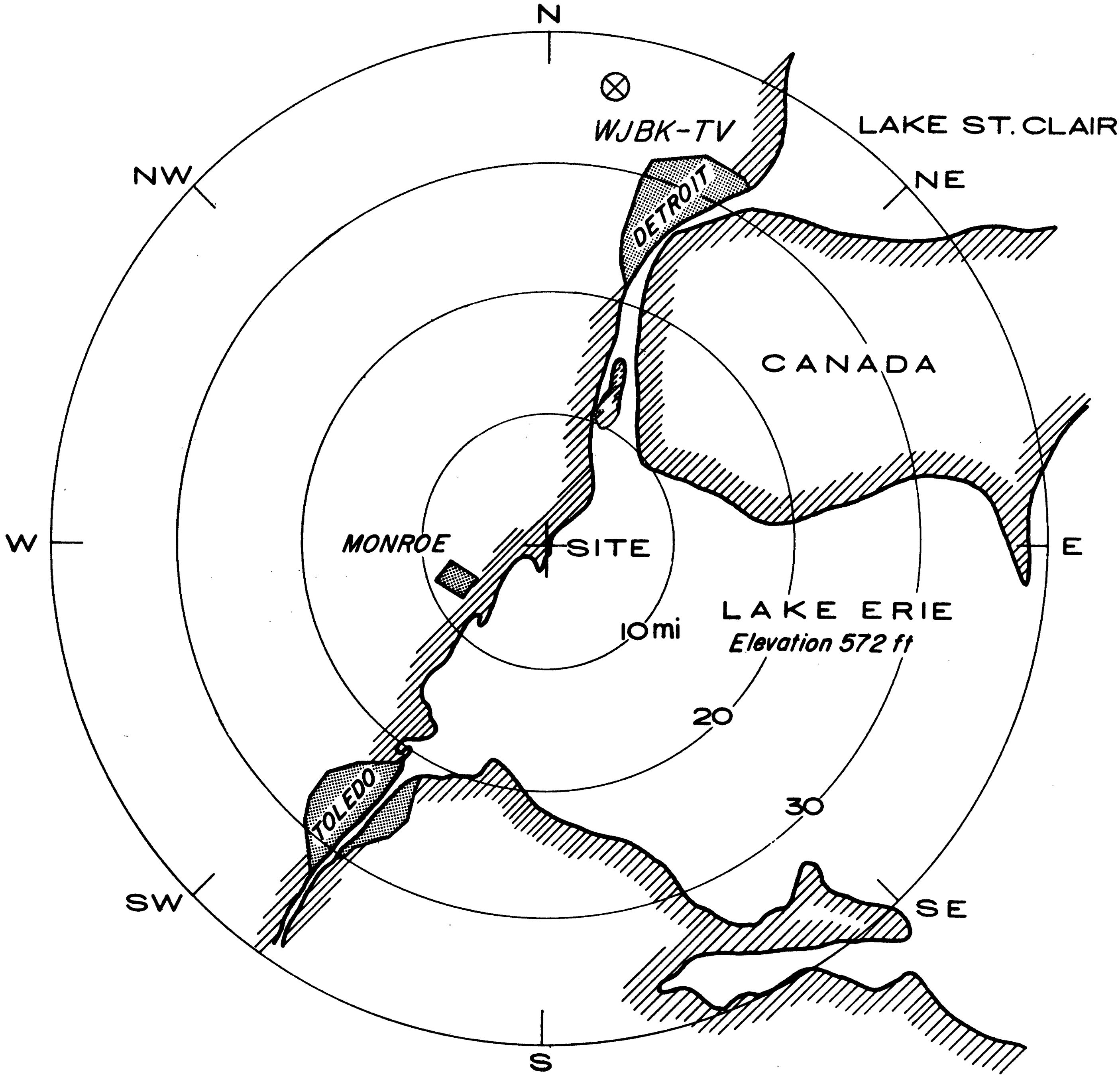


Fig. 1. Area map of Enrico Fermi Nuclear Reactor site and surroundings.

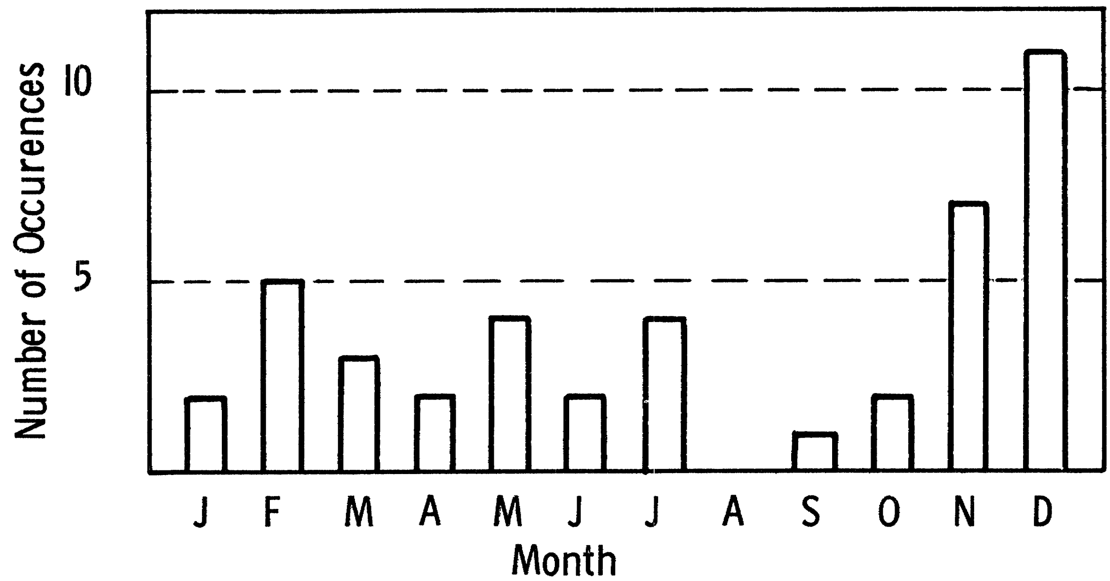


Fig. 2. Distribution of Prolonged Inversions, by months, Dec. 1956-Feb. 1961, Enrico Fermi Site, Monroe, Michigan

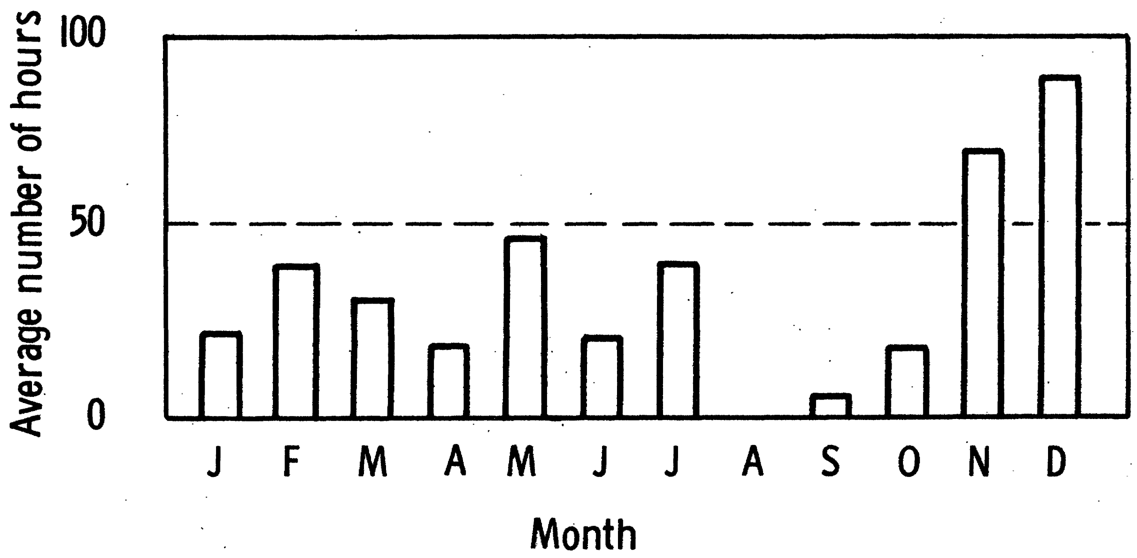


Fig. 3. Average number of hours, by month, of Prolonged Inversions, Dec. 1956-Feb. 1961, Enrico Fermi Site, Monroe, Michigan

The first Prolonged Inversion observed at Monroe in December 1956 persisted 58 hours. However, this duration has been surpassed on six occasions, as may be seen in Fig. 4 in the bar graph of duration against occurrence. The greatest duration of 76 hours was in November 1960.

During the first three years of record at Monroe, temperature observations taken continuously at the WJBK-TV tower at Detroit (Fig. 1) yielded contrasting results. At the latter site, there was but one Prolonged Inversion in the layer between 20 and 300 feet (6). The causes of this difference will be considered in a later section dealing with surface air trajectories.

4. RELATION OF PROLONGED INVERSIONS TO MACROSCALAR SYNOPTIC FEATURES

The surface synoptic map features corresponding to the Monroe area during Prolonged Inversion periods are classified in seasonal summaries in Table 1, and a cross-classification is added in Table II. These tables show that three synoptic map patterns account for about 90 percent of the 25 Prolonged Inversions occurring during the first three years of Enrico Fermi Atomic Power Plant site data. They are as follows:

A. Warm sector or persistent southerly flow.

B. Ridge line NE/SW through the Monroe area.

C. High pressure cell near the Monroe area.

Some details will now be given for each classification:

1. Warm sector

The warm sector cases compose 40 percent of the total, with all of them occurring in fall or winter. The associated low pressure area to the west is usually located in the Great Plains or North Central States during the 24 hours before onset of the inversion. However, the first three years of data do not show any

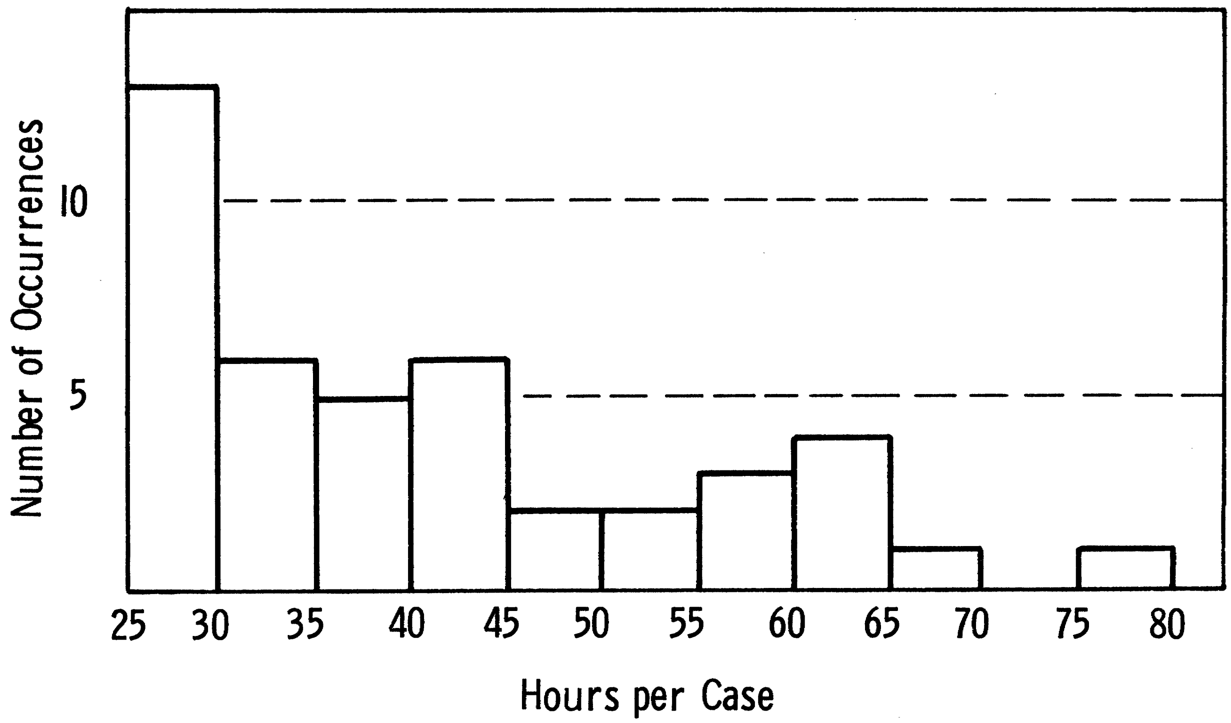


Fig. 4. Distribution of Prolonged Inversions by five-hourly periods, Dec.1956-Feb.1961, Enrico Fermi Site, Monroe, Michigan

preferred location or direction of movement of these cyclones, and filling cases nearly balance deepening cases.

2. Ridge line SW/NE

The ridge line cases are warm advection types, largely, with an anticyclone in the Nova Scotia area usually being related to a weak surface component from the south at the plant site. The timing of the onset and cessation of some of the Prolonged Inversions in in phase with the appearance and disappearance, respectively, of the ridge line.

3. High pressure cell

When they are to the east or southeast, the high pressure cells found nearby during some of the persistent inversions also cause warm advection. These systems move to the Atlantic coast or beyond by the end of the inversion period.

Appendix I lists all of the Prolonged Inversions occurring between December 1956 and February 1961.

5. RELATION OF PROLONGED INVERSIONS TO WIND DIRECTION

Data summaries (6) indicate that a temperature inversion was present 28 percent of the time at the plant site during the three years under discussion, and wind direction during inversions is most commonly from SSE clockwise to WNW. The wind roses for Prolonged Inversions may be contrasted to the above as well as to non-inversion hours, but just the latter winds are entered in the wind roses in Fig. 5-8. The lengths of the lines representing Prolonged Inversions have been adjusted to total 100 percent frequency.

These diagrams show the domination of southwestern quadrant winds in all seasons except summer, with the southeastern quadrant

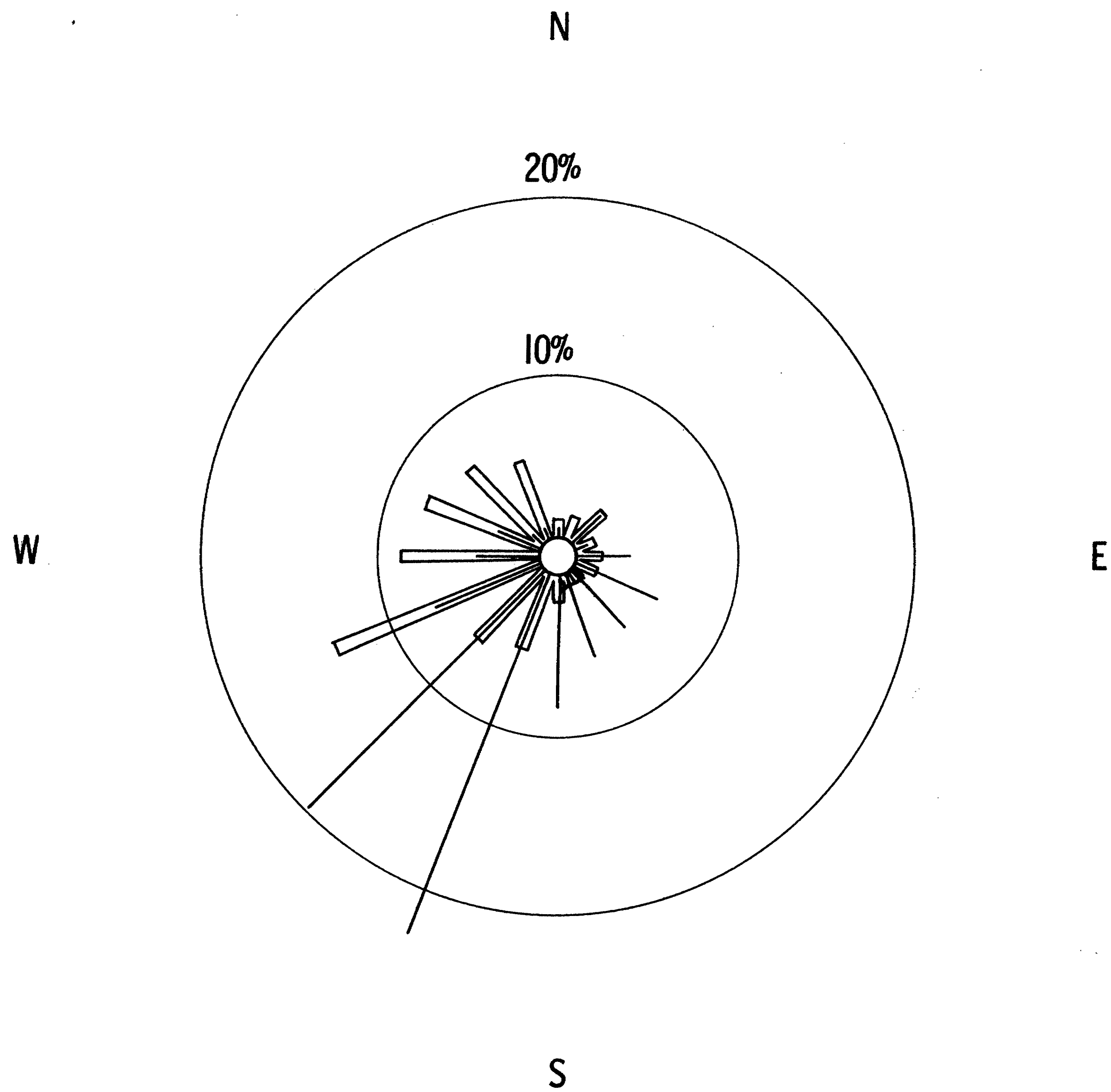


Fig. 5. Percentage frequency of Prolonged Inversions (lines) and noninversions (open bars) associated with wind direction, winter, 1957-59, Enrico Fermi Site, Monroe, Michigan. The line lengths are adjusted to total 100%; the open bars are not adjusted, and they total 76%.

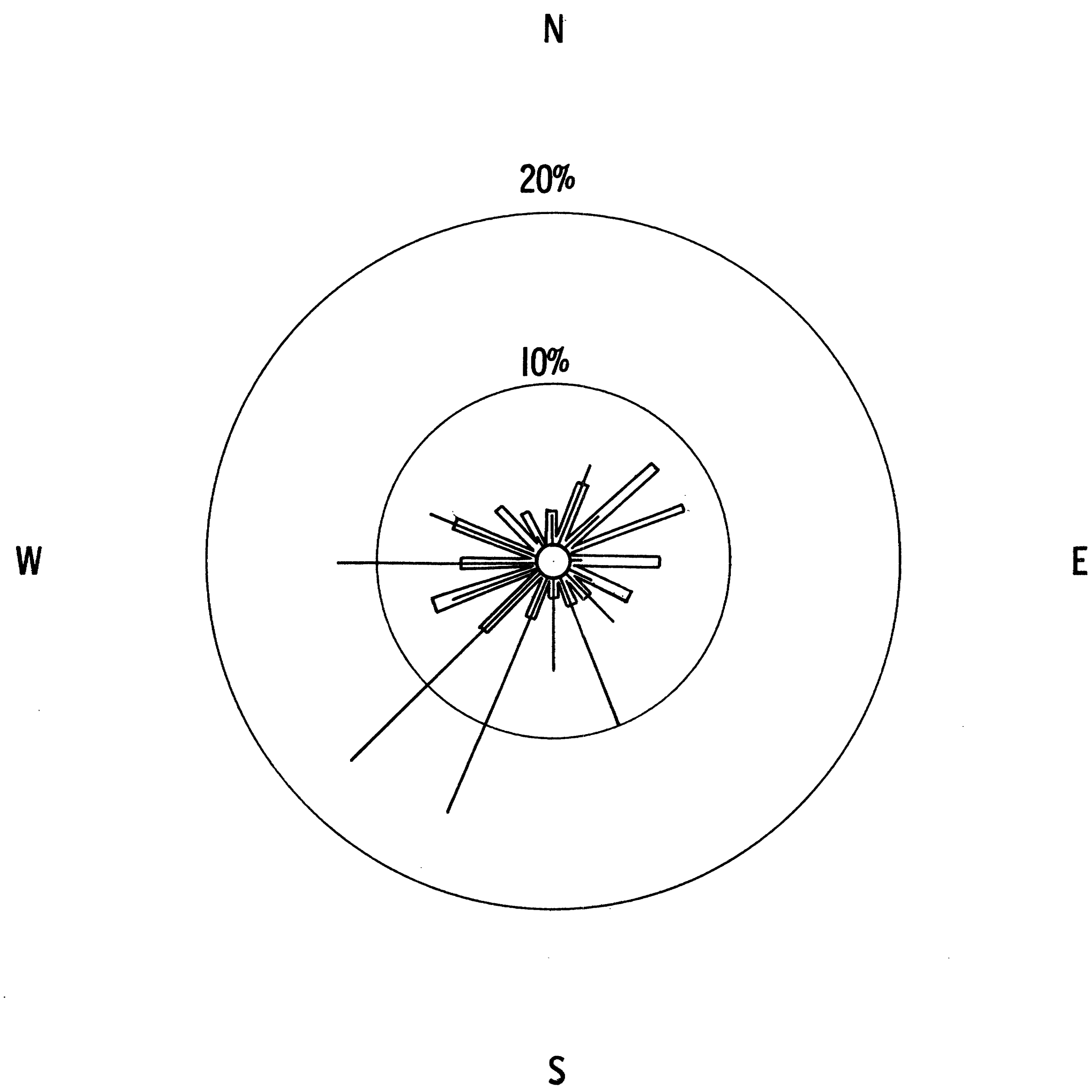


Fig. 6. Percentage frequency of Prolonged Inversions (lines) and non-inversions (open bars) associated with wind direction, spring, 1957-59, Enrico Fermi Site, Monroe, Michigan. The line lengths are adjusted to total 100%; the open bars are not adjusted, and they total 77%.

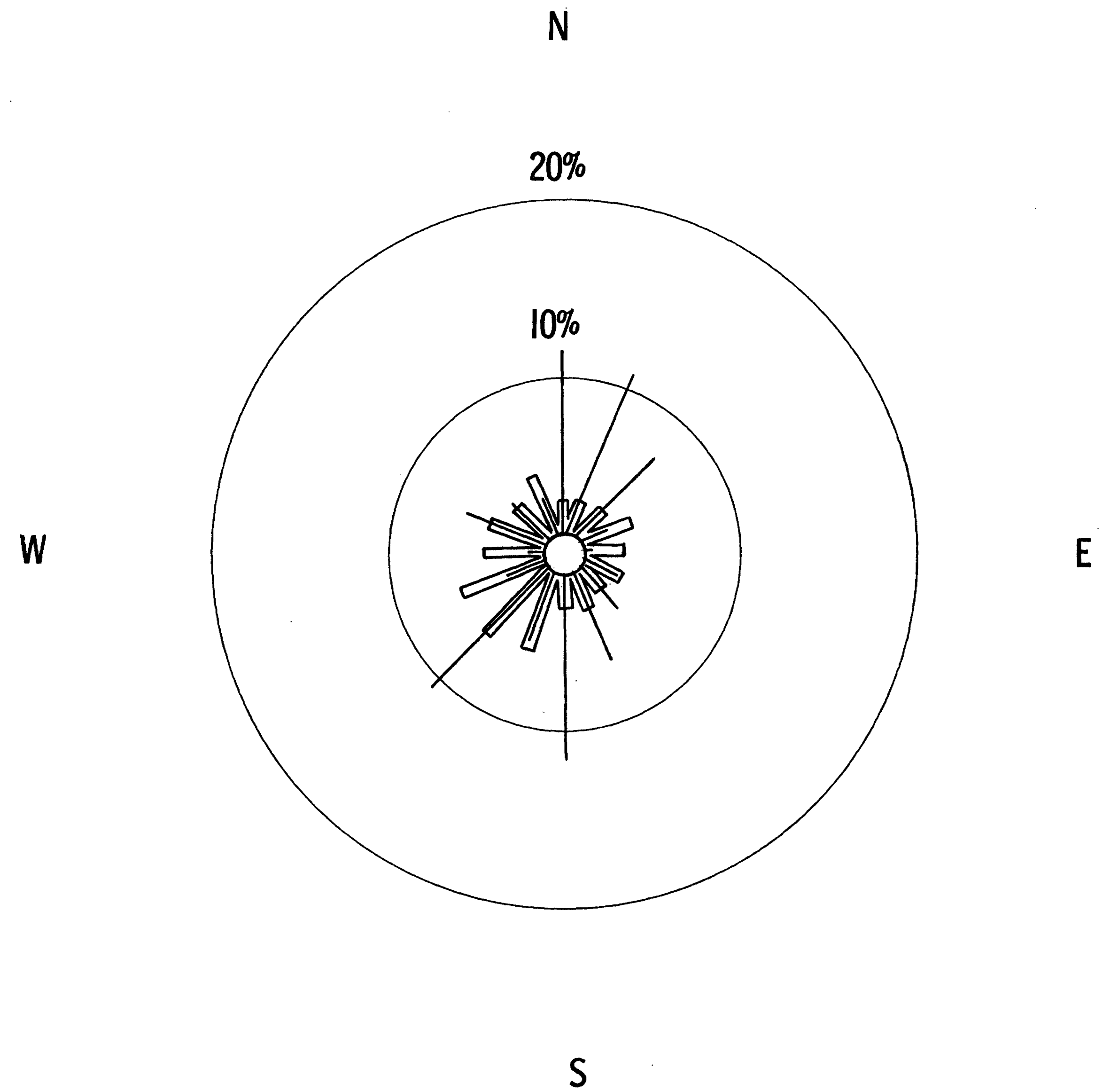


Fig. 7. Percentage frequency of Prolonged Inversions (lines) and non-inversions (open bars) associated with wind direction, summer, 1957-59, Enrico Fermi Site, Monroe, Michigan. The line lengths are adjusted to total 100%; the open bars are not adjusted, and they total 66%.

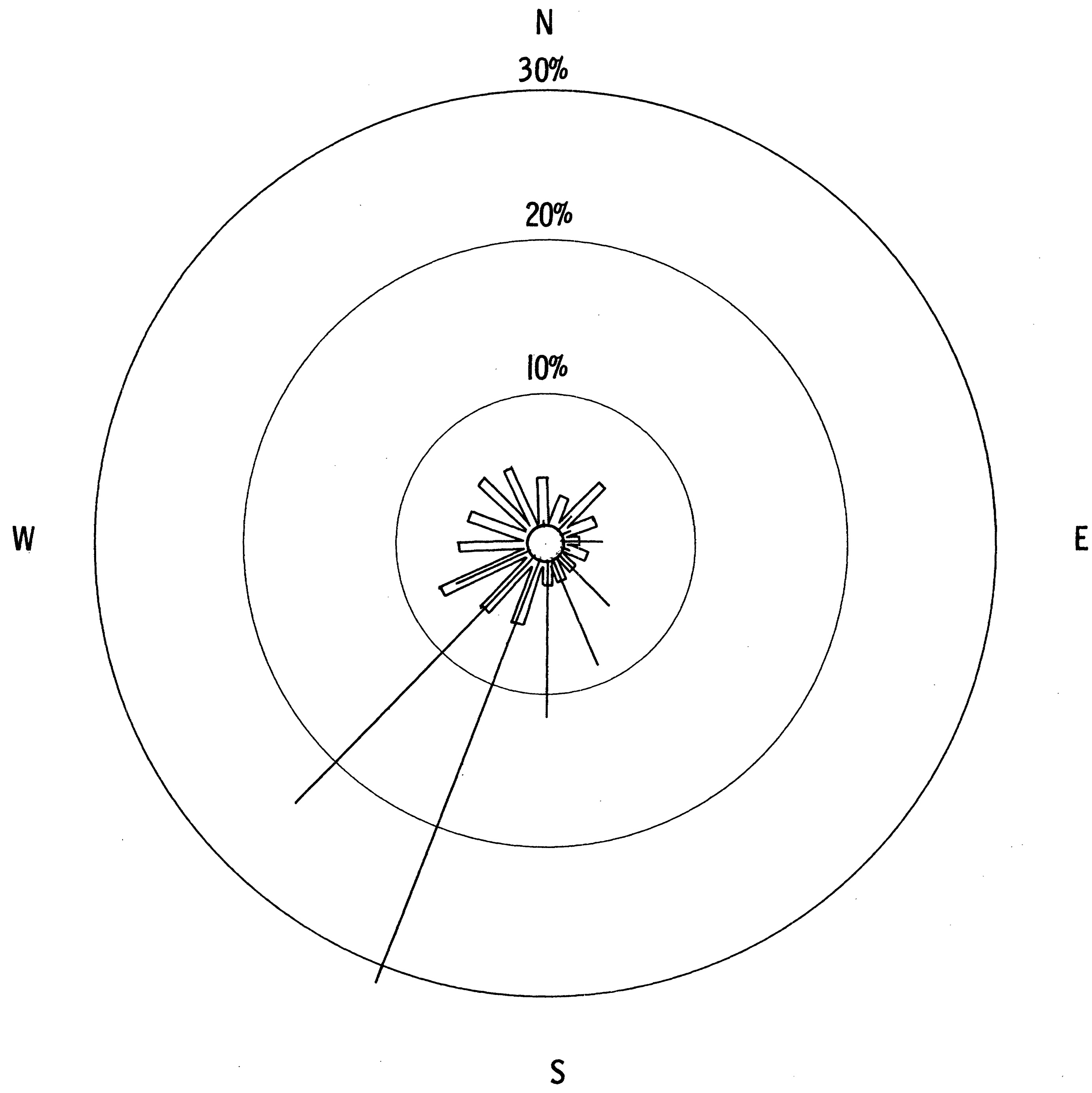


Fig. 8. Percentage frequency of Prolonged Inversions (lines) and non-inversions (open bars) associated with wind direction, fall, 1957-59, Enrico Fermi Site, Monroe, Michigan. The line lengths are adjusted to total 100%; the open bars are not adjusted, and they total 70%.

Table I

SYNOPTIC MAP FEATURES ASSOCIATED WITH PROLONGED INVERSIONS

Enrico Fermi Site

1 December 1956 to 30 November 1959

Winter (Dec-Feb)	Number of Cases
warm sector	2
southwest flow	1
ridge line SW/NE	1
stationary front	1
	5

Spring (Mar-May)	Number of Cases
southwest flow	1
ridge line SW/NE	1
high cell	3
	5

Summer (Jun-Aug)	Number of Cases
weak cold-frontal passage	1
high cell to NW	1
high cell	1
	3

Fall (Sep-Nov)	Number of Cases
warm sector	8
ridge line SW/NE	2
high cell	2
	12

Table II

CROSS-CLASSIFICATION OF INFORMATION IN TABLE I

warm sector	10	(fall/winter)
other S/SW flow cases	2	(winter/spring)
ridge line SW/NE	4	(winter/spring)
front in the area	2	
high cell dominating	7	(all seasons)
	25	

adding a sizable portion of the total. The former winds have a land trajectory, whereas the latter winds come from the lake. In summer, the number of Prolonged Inversions is greatly reduced, and its wind rose, Fig. 7, is distinctive in that the NNE sector supplies over one-third of the total.

6. THE RELATION OF PROLONGED INVERSIONS TO WARM AIR ADVECTION

The macroscalar synoptic features and the wind roses discussed above both point to warm air advection as the cause of the Prolonged Inversions. This was noted previously (4), where the term, "Circulation Inversion", was used to distinguish such cases from radiational (nocturnal) and sea-breeze (diurnal) inversions. Those preliminary comments referred to the northward movement of warm air across the western tip of the lake, the warm air being cooled by the surface water to form the inversion.

Taking into account all prolonged Inversions from December 1956 to November 1959, the surface air parcels arriving at the plant site each 12 hours during an inversion period are found to have these precedent trajectories:

Table III

TRAJECTORIES OF SURFACE AIR PARCELS ARRIVING AT PLANT SITE DURING PROLONGED INVERSIONS

	Number of Cases	Percent Frequency
Lake trajectory, $T_a > T_w$	13	15
Lake trajectory, $T_a < T_w$	13	15
Land trajectory	34	39
SSW sector	27	31
	87	100

$T_a > T_w$ - surface air warmer than surface lake water*

$T_a < T_w$ - surface air colder than surface lake water

*The lake water temperature is measured daily at the Monroe city waterworks. It is representative of the western portion of Lake Erie.

The category termed, "SSW sector", includes those cases where the surface air comes along the shore from the Toledo area and cannot be classified with certainty.

When $T_a > T_w$, the heat transfer in a maritime trajectory is downward to the water, but at a slow rate because of stable conditions. The 15 percent of total cases falling into this category tend to maintain or develop inversions in the lowest levels because of the surface cooling over the water. The observational site on the shore gives a similar lapse rate for air coming toward the land.

When $T_a < T_w$, an inversion over the water in the lowest few feet is not probable. However, if the time spent over the water is too short to break down a previous land inversion, a low-level discontinuity may reach the plant site. This is evidently what happens when a Prolonged Inversion is recorded with $T_a < T_w$.

Previously, it was stated that only one Prolonged Inversion occurred at the WJBK-TV tower at Detroit while there were 10 per year on the Lake Erie shore. The suspected cause of this difference is the contrast in surface air trajectories under conditions of warm air advection. Thus, precedent warm air trajectories at the television tower commonly lie over several miles of well populated suburbs, with appreciable urban climatic influences. On the other hand, the usual trajectories at the lakeshore site come from level farmlands or coastal waters. The deeper layer of 280 feet measured at Detroit may be a second factor in the elimination of most Prolonged Inversions from the record there.

7. STAGNANT ANTICYCLONES

Korshover (7) discussed anticyclones persisting four days or more over the United States. In the 21 years of record treated by him, surface highs did not persist as many as four days in the Monroe area

in winter, but there were 14 cases between April and October. When these cases are graphed and compared with the occurrence of Continuous Inversions (Fig. 9), it is seen that the two are unrelated. From this result, one must conclude that the stagnation of anticyclones in the Monroe area does not cause Prolonged Inversions near the ground, as does the advection of warm air.

To investigate the lapse rate during stagnant anticyclonic conditions, data from the plant site were compared with six anticyclonic cases in concurrent years located in the U.S. Weather Bureau Daily Map Series (Table IV). The six cases all fall within the April to October peak period for stagnating anticyclones in the Monroe area, as is seen in Fig. 9. Only the final case in July 1959 shows any tendency for a Continuous Inversion to form during the presence of the high pressure cell. In fact, over half of the hours have positive lapse rates, confirming that the air near the ground does not participate in the subsidence, but acts as a shielding layer.

Table IV

STAGNANT ANTICYCLONES OF FOUR DAYS OR MORE DURATION

Enrico Fermi Atomic Power Plant

1 December 1956 - 30 November 1959

Anticyclonic Period of 4 Days or More	Lapse Rate Type I(hr)	W(hr)	S(hr)	Missing Data(hr)	Total(hr)
1957 Jly 16 - 20	20	30	72	3	125
Aug 6 - 10			89	18	107
Oct 10 - 15	19		85		104
1959 Jun 3 - 10	20	16	22	122	180
Jly 9 - 17	55	55	18	60	188
Jly 25 - 29	57	26	17	3	103
Total No. of hours	171	127	303	206	807
Percent frequency	21	16	38	25	100

I - inversion present
W - lapse rate nil or weak
S - strong lapse rate

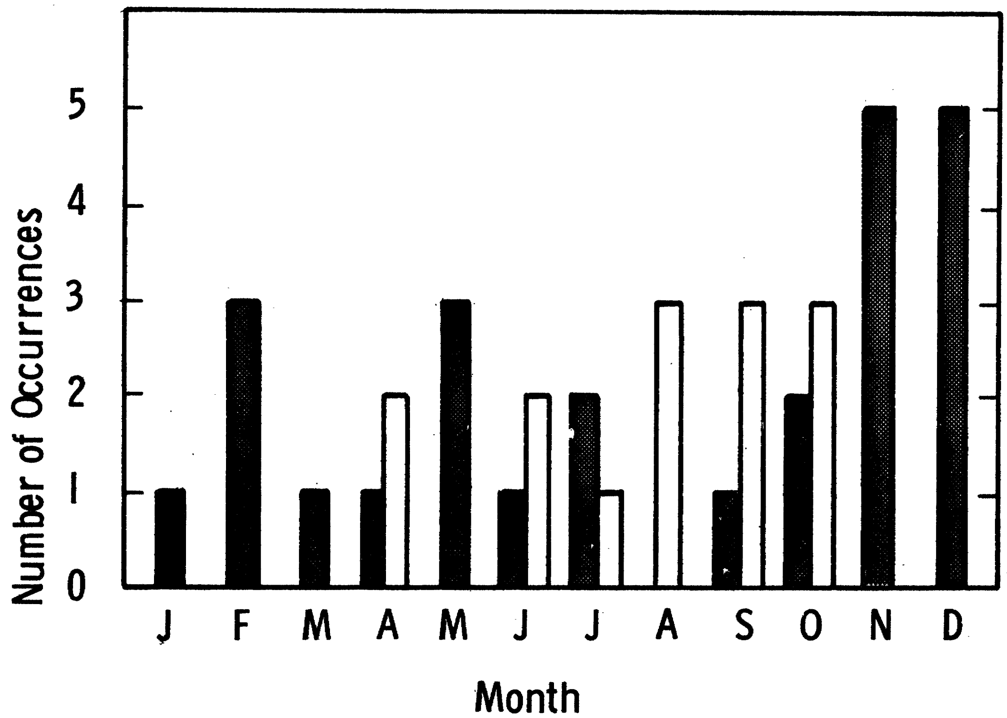


Fig. 9. Distribution by months of Prolonged Inversions, Dec. 1956-Nov. 1959, Enrico Fermi Site, Monroe, Michigan (solid bars) and distribution by months of stagnant anticyclones in the Monroe area, 1936-1956 (open bars).

A small amount of turbulence therein is sufficient to cause a temperature inversion to form at the top of the shielding layer, but the base of the inversion is evidently above the 100-foot tower. A check of Flint, Michigan, radiosonde data reveals the presence of such temperature discontinuities in five of the six cases. They are all continuous in time, and they break down about one day prior to the termination of the period found to be under anticyclonic control. More details on the subsidence inversions are presented in the following table:

Table V

SUBSIDENCE INVERSIONS OCCURRING AT FLINT, MICHIGAN DURING PERIODS OF ANTICYCLONIC DOMINATION

Period	Inversion Layer	Intensity	Sounding Interval
16-19 July 1957	850-940 mb	2-4°C	6-hourly
6-8 Aug 1957	710-870	2-4	Do.
10-13 Oct 1957	810-870	2-6	12-hourly
4-10 June 1959	720-850	1-4	Do.
9-17 July 1959	weak or absent		Do.
25-27 July 1959	850-900	1-3	Do.

8. FORECAST PROCEDURE FOR PROLONGED INVERSIONS

As was shown in Table II, the onset of a Prolonged Inversion is related to the occurrence of three synoptic patterns: warm sector, NE/SW ridge, or temporary high cell in the vicinity of Lake Erie. After the favorable synoptic type is established, however, there is often a lag of a few hours before the inversion becomes continuous. The termination is frequently linked to the breakdown of the synoptic type, as, for example, in the passage of a cold front. A simple forecasting procedure, then, is to prognose the beginning and the ending of the three associated map features, and to fit in the inversion predictions accordingly, with some lag in the onsets. To increase forecasting skill, however, the use of a warm air advection parameter is advisable.

A. Prediction of Inversion Onset

As a measure of warm air advection at the surface, the southerly wind component was selected, and its average value over the periods 0400-0800 EST and 1100-1500 EST were computed from the anemographical record. Since the 100-foot Aerovane record from the tower was the most accessible wind information, it was used throughout this part of the investigation. The southerly wind component at 100 feet, $\bar{v}_s$, has a speed of about ten percent more than the surface wind.

For a second parameter suitable for plotting against $\bar{v}_s$ in a graphical forecast method, a measure of temperature was sought. The basis for this quest is found in the fact that the lake breeze phenomenon may perpetuate an inversion at the plant site when $\bar{v}_s$ is not indicating an inversion occurrence, and the lake breeze depends, in part, upon the land-water temperature contrast. For simplicity, ΔT_{min}, the departure of the minimum temperature from the monthly mean* was chosen. This, too, is a quantity to be forecast.

Figs. 10-12 show some of the plots of $\bar{v}_s$ against ΔT_{min}. Summer is excluded here, because of the known lack of correlation between $\bar{v}_s$ and inversion occurrences in this season. Since there is a peak in November-December in the occurrence of Prolonged Inversions (Fig. 2), a rearrangement of the months into new quarters was considered desirable at this stage. The change applies to Figs. 10-12, and it consists of the grouping of January through March to form "Winter", April through June for "Spring" and October through December for "Fall". The Prolonged Inversion cases in winter do not group well (Fig. 10), but spring (Fig. 11) and fall

*Monthly mean minimum temperatures are listed in Appendix II.

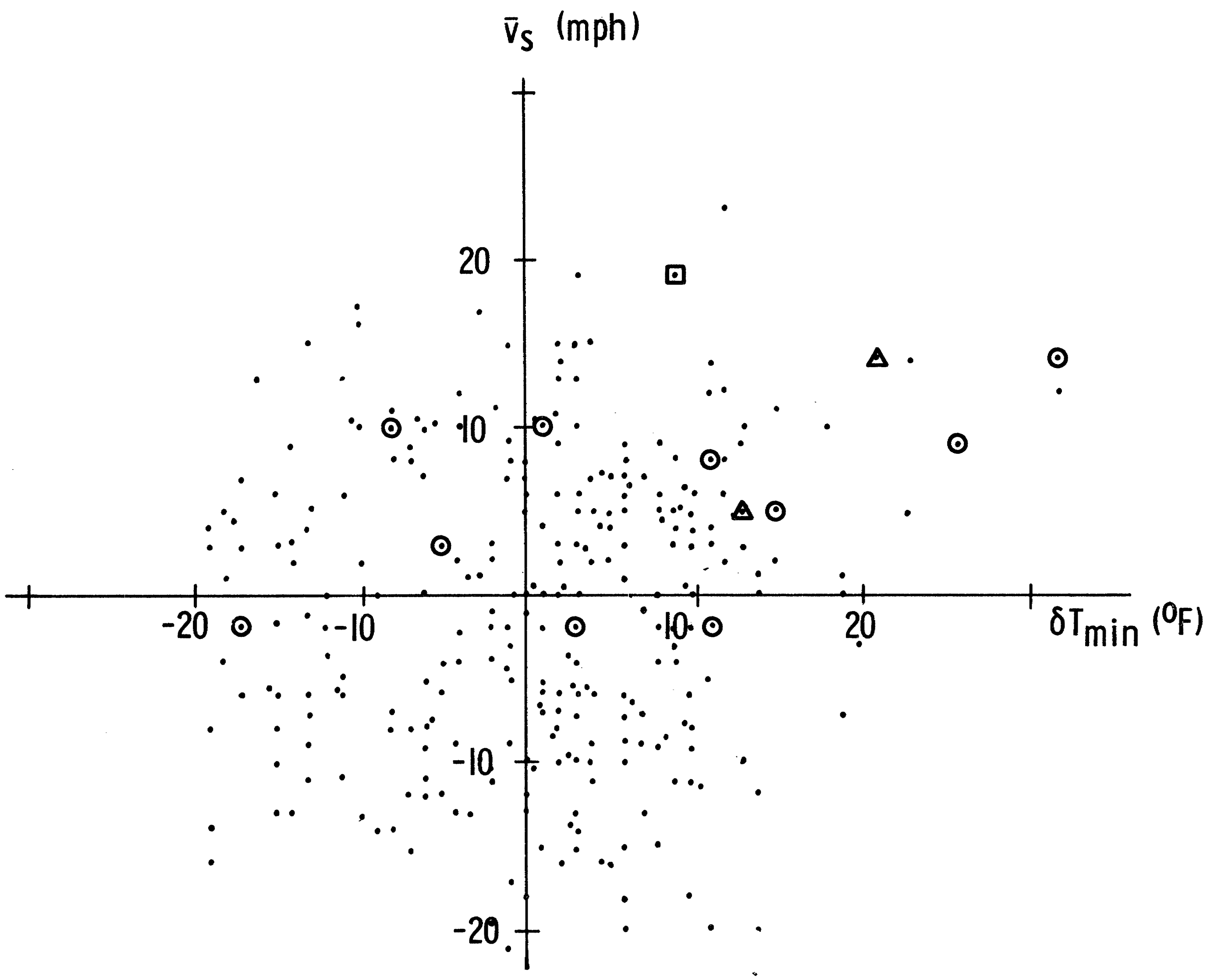


Fig. 10. Departure from monthly means of the minimum temperature (δT_{min}) versus average southerly wind component, 1100-1500 EST ($\bar{v}_s$), January-March, 1957-1960, Enrico Fermi Site, Monroe, Michigan. Each dot represents one day.

⊙ Prolonged Inversion Day

⊡ A day with brief inversion absences, or with an early beginning of a Prolonged Inversion

△ A day with a Prolonged Inversion interrupted by a frontal passage

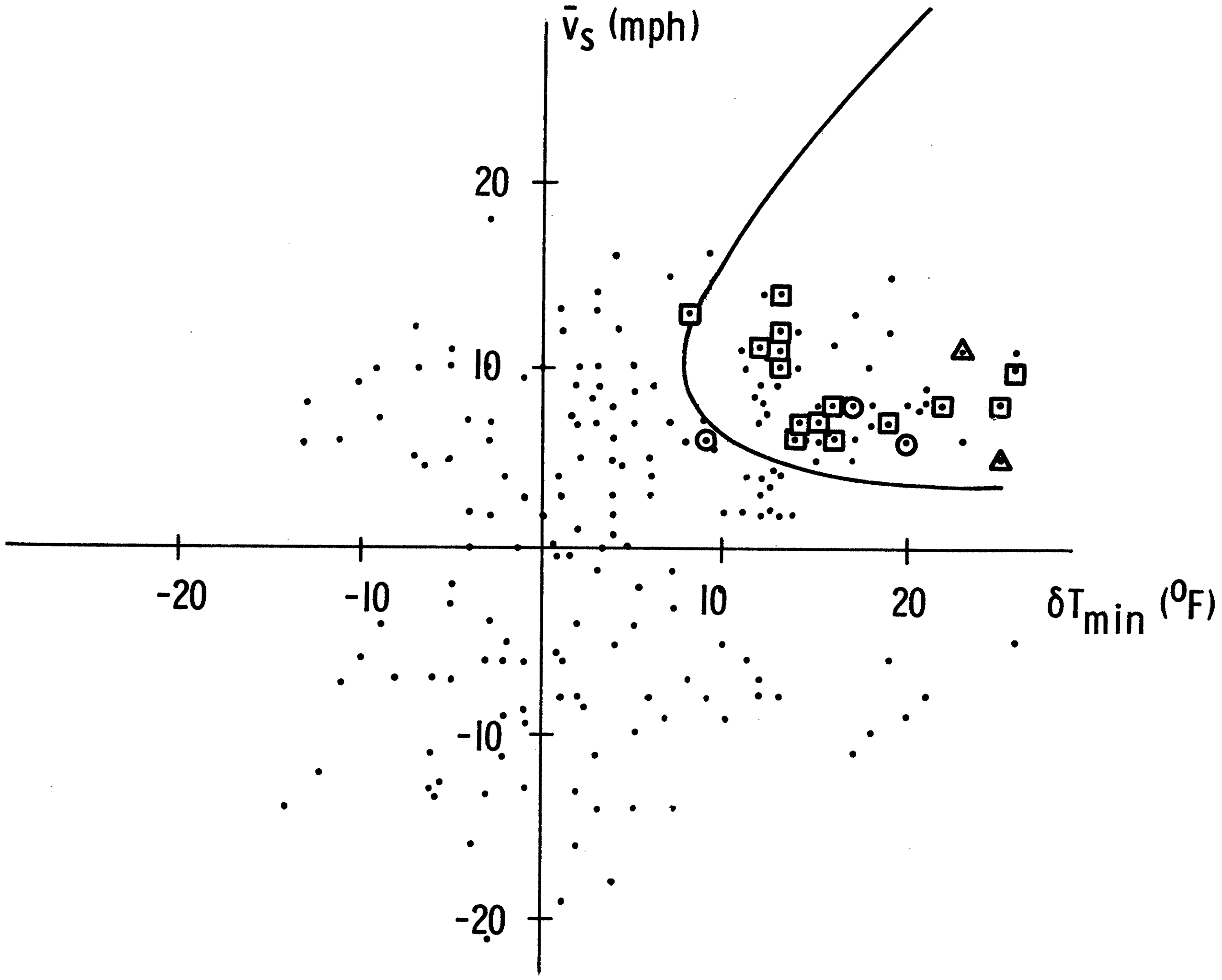


Fig. 11. Departure from monthly means of the minimum temperature (δT_{min}) versus average southerly wind component, 1100-1500 EST ($\bar{v}_S$), April-June, 1957-60, Enrico Fermi Site, Monroe, Michigan. Each dot represents one day.

⊙ Prolonged Inversion Day

⊡ A day with brief inversion absences, or with an early beginning of a Prolonged Inversion

⚠ A day with a Prolonged Inversion interrupted by a frontal passage.

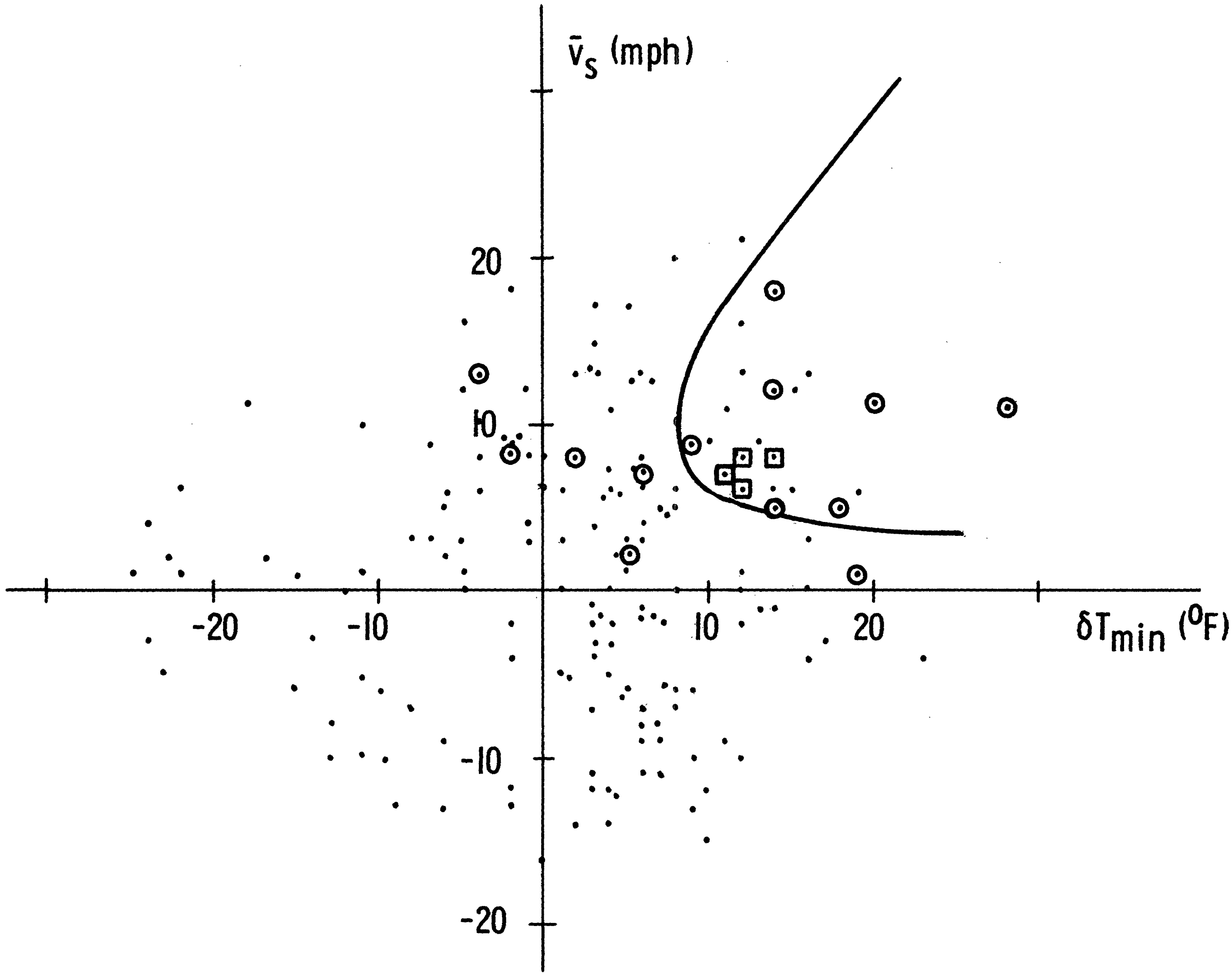


Fig. 12. Departure from monthly means of the minimum temperature (δT_{min}) versus average southerly wind component, 1100-1500 EST ($\bar{v}_s$), December 1956, October-December, 1957-58, and December 1959, Enrico Fermi Site, Monroe, Michigan. Each dot represents one day.

⊙ Prolonged Inversion Day

⊡ A day with brief inversion absences, or with an early beginning of a Prolonged Inversion.

△ A day with a Prolonged Inversion interrupted by a frontal passage.

(Fig. 12) cases tend to fall in Quadrant I, to the right of a curve through coordinates (16,24), (10,16), (8,10), (10,6) and (16,4). There are no notable differences between the two four-hour periods tested for $\bar{v}_s$, and the curve of separation is essentially the same in all of the spring and fall scattergrams.

After the Prolonged Inversion cases in these figures had been encircled, the remaining points to the right of the curve were examined. Many of these points fall into one of the following categories:

1. The occurrence of a two or three-hour period with missing data or a weak lapse rate, breaking up a Continuous Inversion which, by definition, permits only one such hour.
2. The beginning of a Prolonged Inversion early in a calendar day.
3. The termination of a Prolonged Inversion by a frontal passage, again throwing out that calendar day from the count.

The above cases were marked specially by a square (for categories 1 and 2) or triangle (for category 3) in Fig. 10-12. Further details on these figures are found in Appendix III.

B. Prediction of Inversion Termination

As is indicated above, the disruption of warm air advection is a means of predicting the termination of the low-level inversions. A frontal passage is the most common cause of such a disruption of the advection, but in the 4¼ years of data, just 12 of 39 terminations are definitely due to frontal passages, leaving a sizable number of cases to be examined further.

From a theoretical standpoint, there is a cause and effect relationship between the lapse rate and wind speed in the lowest layer. As was pointed out (3), when a strong lapse rate occurs, momentum transport downward is enhanced, increasing the surface wind. Conversely, with an inversion present, suppose that the surface wind speed is strengthened by a tightening pressure gradient or a density effect. Then the inversion may well be supplanted by an increasing lapse rate, and perhaps there is a critical wind speed at 100 feet beyond which inversions between 25 and 100 feet will not persist.

Investigation of Prolonged Inversion terminations disclosed three instances when such wind increases occurred, apparently breaking the inversion each time when the 100-foot wind speed reached 30 mph. Winds as great as 30 mph were then checked through the available record without finding a single inversion hour. Therefore the prediction of speeds as great as 30 mph can be used in addition to frontal passages in timing the ending of a Prolonged Inversion.

On four occasions, precipitation began simultaneously with the termination of a persistent inversion, but mere coincidence is suspected, there being numerous cases when precipitation had no effect. The two forecasting tools found, then, are the frontal passages and the critical wind speed of 30 mph.

9. TESTING OF FORECAST PROCEDURE

When additional data subsequent to November 1959 became available, a test period was established to check the performance of the graphical procedure. Once again, actual values of $\bar{v}_s$ and δT_{min} were used,

rather than forecast values, and δT_{min} was calculated from the monthly means, excepting that the mean used the last five days of a particular month, and the first five days of the succeeding month, was the average of the two monthly means. The single graph for the test period of September 15, 1960, to February 14, 1961, is shown in Fig. 13, where the separation curve is drawn identically to Fig. 10-12.

Surprisingly, since the winter months had not grouped well in the first trial, the eight Prolonged Inversion days all lie to the right of the curve. The other points to the right include four in the three special categories and 13 misses. A chronological picture of this period is given in Fig. 14, which also shows the result of an earlier inspection of U.S. Weather Bureau Daily Maps to pick out days when the Monroe area was under the influence of one of the three related synoptic types. The agreement among the chart inspection, the graphical aid routine and the Prolonged Inversions is striking. It is also evident that the graphical procedure is a notable improvement over chart inspection alone. Further details on Fig. 13 are found in Appendix III.

10. SUMMARY OF FORECAST PROCEDURE

The following simple forecasting procedure is suggested for spring, fall, and winter in predicting the positive occurrence of inversions exceeding 24 continuous hours at the Enrico Fermi Atomic Power Plant site.

A. Check the surface prognostic charts for pronounced warm air advection into the Monroe area. In particular, watch for the future influence of a warm sector, a NE/SW ridge or an anticyclonic center within 300 miles to the east or southeast.

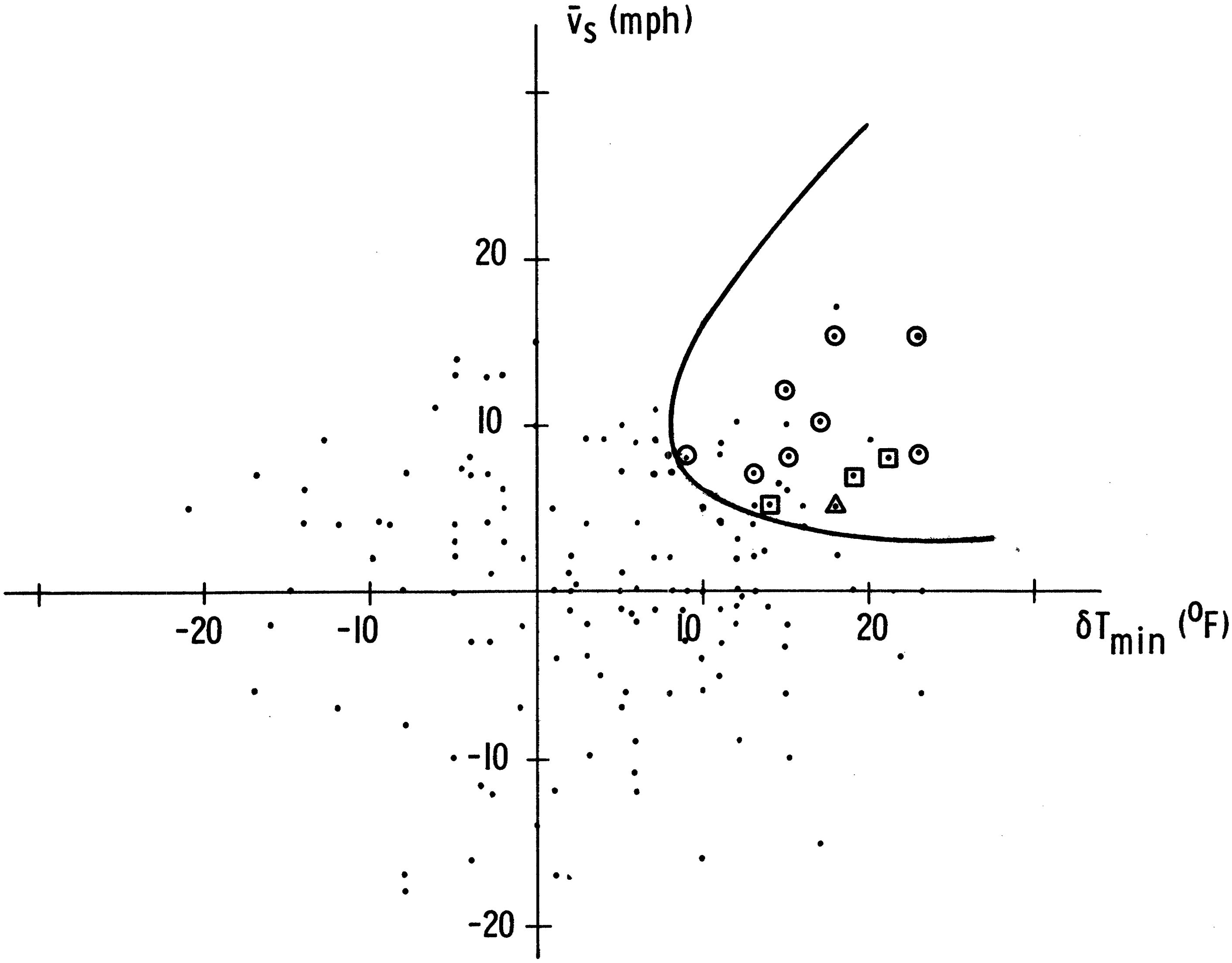
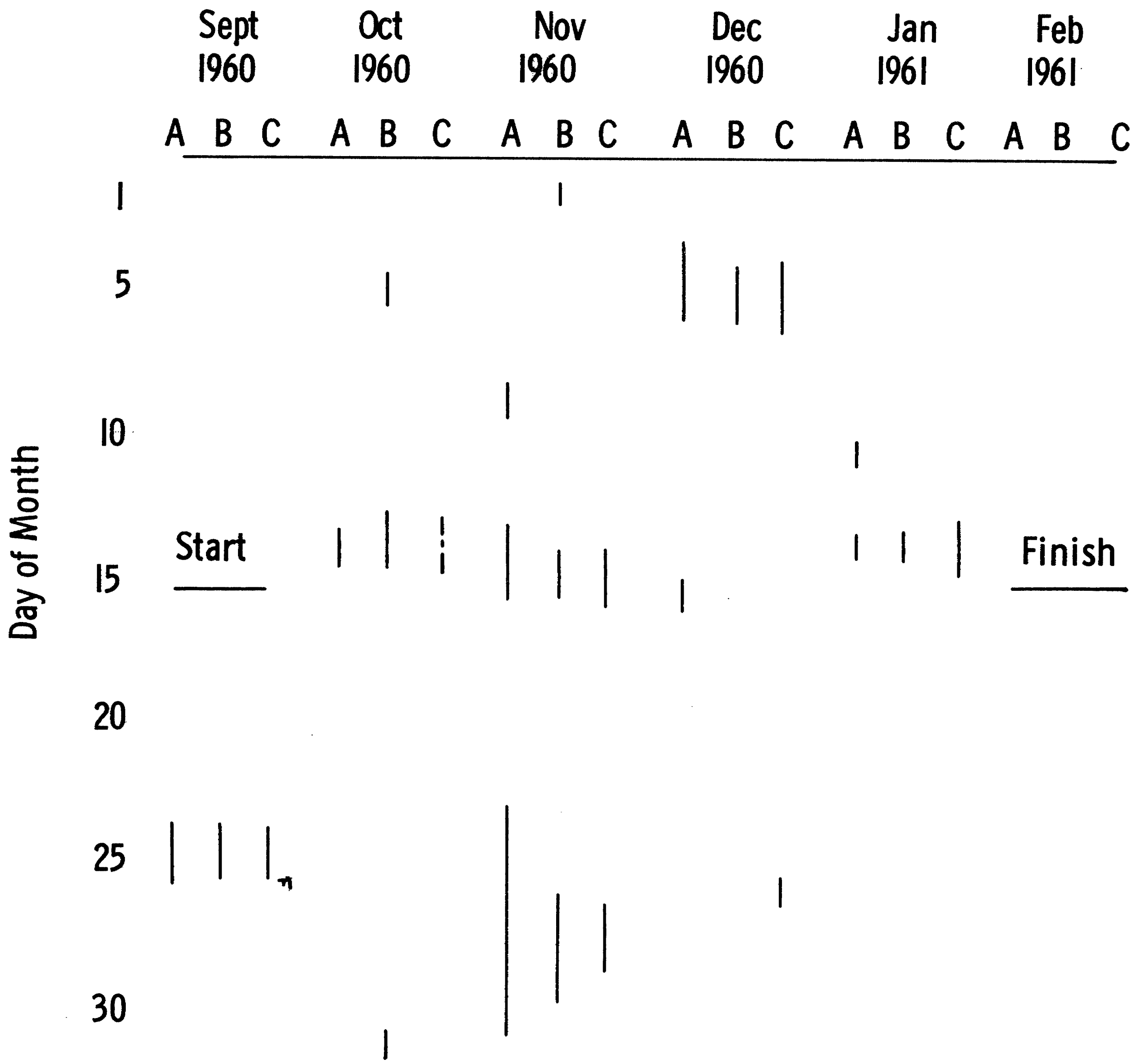


Fig. 13. Departure from monthly means of the minimum temperature (δT_{min}) versus average southerly wind component, 1100-1500 EST ($\bar{v}_S$), September 15, 1960 to February 14, 1961, Enrico Fermi Site, Monroe, Michigan. Each dot represents one day.

⊙ Prolonged Inversion Day

⊡ A day with brief inversion absences, or with an early beginning of a Prolonged Inversion.

△ A day with a Prolonged Inversion interrupted by a frontal passage.



Columns lettered "A": Suspected Prolonged Inversion days, based on chart inspection

Columns lettered "B": Prolonged Inversion days forecast, based on a graph of δT_{min} versus $\bar{v}_s$

Columns lettered "C": Type of day recorded

——— Prolonged Inversion

—·— Prolonged Inversion, with brief lapses

———ᶠ Prolonged Inversion, interrupted by a frontal passage.

Fig. 14. A test of chart inspection and graphical aid in the prediction of Prolonged Inversions at Enrico Fermi Site, Monroe, Michigan

B. When warm advection or a positive temperature departure is expected, plot δT_{min}, the forecast morning minimum temperature in °F., against $\bar{v}_s$, the south wind component in mph at 100 feet, 1100-1500 EST, and note the location of the plotted point with reference to a curve through coordinates (16,24), (10,16), (8,10), (10,6) and (16,4). If the point lies on the right side of the curve, a Prolonged Inversion, i.e., a Continuous Inversion lasting more than 24 hours, should be predicted.

C. When a Prolonged Inversion is present, or has been predicted, forecast its termination to be coincident with the next cold frontal passage or the occurrence of wind speeds as great as 30 mph at 100 feet.

11. CONCLUSIONS

Prolonged Inversions in the lowest 100 feet along the western shore of Lake Erie have their peak frequency in the months of November and December. Three consecutive days of a Continuous Inversion has been the maximum duration in the first 4¼ years of record. The minimum in monthly frequency lies in August and September.

Three synoptic map patterns centered on the Monroe, Michigan area account for most of the inversion cases, that is, they appear shortly before a Prolonged Inversion begins and disappear near the time of termination. These three types are:

A. Warm sector or persistent southerly flow.

B. Ridge line SW/NE through the Monroe area.

C. High pressure cell near the Monroe area to the east or southeast.

The domination of southerly or southwesterly winds during the Prolonged Inversions is quite marked in all seasons excepting summer.

This agrees with the three principal synoptic patterns, and it points to warm air advection as the cause of the longer inversions.

Surface air parcels arriving at the Enrico Fermi Atomic Power Plant site during Prolonged Inversion periods have land trajectories about 40 percent of the time, with the remainder being divided equally between shore and lake trajectories.

Stagnant anticyclones lasting four days or more do not exhibit any close relationship to Prolonged Inversions in the area under consideration, there being a shielding layer in the lowest levels.

A forecast method using a graphical plot of warm air advection in the form of the average south wind component, 1100-1500 EST, as the first parameter, against the anomaly in the minimum temperature, as the second parameter, should be quite successful in predicting the positive onset of Prolonged Inversions. However, a rather large number of predicted occurrences will not materialize, and these must be reduced if a high skill score is to be attained.

Using frontal passages and 100-foot wind speeds of 30 mph or more as terminating factors, about one-third of all inversion terminations can be forecast accurately, on the basis of the results presented in this report.

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APPENDIX I

LOG OF PROLONGED INVERSIONS

Date			No. of Hours	Surface Feature
1956	Dec	4- 6	58	Warm sector
1957	Feb	24-26	43	Southerly flow into warm sector case
	Mar	13-15	34	Warm sector
	May	24-25	26	Warm high centered just south of Monroe
	Jly	22-24	50	High to NW near Lake Superior
	Dec	9-10	28	Ridge line SW/NE
	Dec	19-20	35	Warm sector
1958	Feb	23-24	25	Stationary front
	May	20-23	65	Cold high with cold front passage
	Jly	25-27	43	Weak cold front passage and high cell
	Sep	22-23	25	Warm high
	Oct	6- 7	29	Receding high
	Oct	14-15	44	Warm sector
	Nov	13-14	25	Warm sector
	Nov	14-15	40	Warm sector
	Nov	17-18	33	Warm sector
	Dec	25-26	30	Cold high
	Dec	27-29	42	Ridge line SW/NE
1959	Jan	26-29	59	Ridge line SW/NE
	Feb	12-13	25	Southwest flow
	Apr	22-24	35	Ridge line SW/NE
	May	19-20	35	Southwest flow

LOG OF PROLONGED INVERSIONS (Con't)

Date			No. of Hours	Surface Feature
1959	Jun	8-10	56	Lobe of Bermuda High
	Nov	4- 5	26	Warm sector
	Nov	21-23	47	Warm sector
	Dec	1- 2	26	
	Dec	3- 5	33(?)	
	Dec	16-17	29	
	Dec	25-28	76	
1960	Feb	4- 6	38	
	Mar	14-16	31	
	Mar	28-30	61(?)	
	Apr	2- 3	36	
	May	3- 6	62	
	Jun	25-26	30	
	Jly	11-13	43	
	Jly	16-17	25	
	Nov	14-16	49(?)	
	Nov	26-28	64	
	Dec	3- 6	60	
	Dec	25-26	25	
1961	Jan	12-14	53	
	Feb	8- 9	29	

APPENDIX II

MONTHLY MEAN SURFACE AIR TEMPERATURES FOR DETROIT AREA*

	Minimum	Maximum
Jan	18°F.	33°F.
Feb	17	35
Mar	25	45
Apr	37	56
May	47	68
Jun	56	77
Jly	61	81
Aug	59	80
Sep	52	73
Oct	42	61
Nov	32	47
Dec	24	36

*From Visher, S.S., Climatic Atlas of the United States, Harvard University Press, 1954.

APPENDIX III

DETAILS ON FIGURES 11 TO 13

Fig. 11: April-June, 1957-1960

Points to the left of the separation curve include:

1 Prolonged Inversion with brief lapses

Date: 25 May 1957

Total number of points on the separation curve: 1

1 Prolonged Inversion

Date: 25 May 1957

Total number of points to the right of the separation curve: 53

2 Prolonged Inversions

Dates: 9 Jun 1959; 10 Jun 1959

14 Prolonged Inversions with brief lapses

Dates: 23 Apr 1957; 17 Jun 1957; 29 Jun 1958; 30 Jun 1958;
17 Apr 1959; 25 Apr 1959; 19 May 1959; 20 May 1959;
26 May 1959; 27 May 1959; 5 Jun 1959; 21 Jun 1959;
27 Jun 1959; 28 Jun 1959

2 Prolonged Inversions with frontal passages

Dates: 26 April 1957; 27 April 1957

35 missed forecasts

Fig. 12: December 1956; October-December, 1957-1958;
December 1959

Points to the left of the separation curve include:

6 Prolonged Inversions

Dates: 15 Nov 1958; 1 Dec 1959; 4 Dec 1959;
16 Dec 1959; 26 Dec 1959; 27 Dec 1959

Total number of points to the right of the separation curve: 23

Fig. 12 (Con't)

7 Prolonged Inversions

Dates: 5 Dec 1956; 6 Dec 1956; 20 Dec 1957; 7 Oct 1958;
13 Nov 1958; 14 Nov 1958; 17 Nov 1958

4 Prolonged Inversions with brief lapses

Dates: 15 Dec 1956; 14 Oct 1958; 15 Oct 1958; 16 Oct 1958

12 missed forecasts

Fig. 13: September 15, 1960 - February 14, 1961

Total number of points to the right of the separation curve: 24

8 Prolonged Inversions

Dates: 14 Nov 1960; 15 Nov 1960; 26 Nov 1960; 27 Nov 1960;
28 Nov 1960; 4 Dec 1960; 5 Dec 1960; 13 Jan 1961

3 Prolonged Inversions with brief lapses

Dates: 24 Sep 1960; 13 Oct 1960; 14 Oct 1960

1 Prolonged Inversion with frontal passage

Date: 25 Sept 1960

12 missed forecasts